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OFFICE OF NAVAL RESEARCH

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Task Order

Technical Report No. 1

SEISMIC CRUSTAL STUDY IN THE CHUKCHI SEA

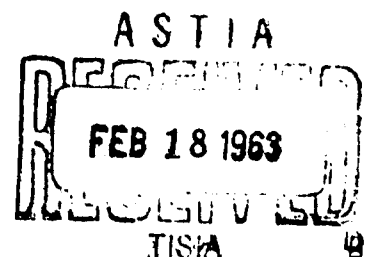
by

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INTRODUCTION

During the period from June 22 to September 12, 1961, a seismic refraction study of the emerged and submerged coastal plain of northern Alaska was started in an attempt to determine the structure of the earth's crust in that area. This seismic study is part of a broad program of gravity, magnetic, and seismic investigations of the Arctic Ocean basin sponsored by the Office of Naval Research. The gravity and magnetic studies are being conducted by the University of Minnesota. This report deals with the results of the first summer of seismic investigation.

The late Dr. Edward Thiel was the principal investigator and field party leader. He was assisted by graduate students Dennis D'Andrea, James Olson, and Karl Veith. Ned A. Ostenso from the University of Wisconsin's Geophysical and Polar Research Center replaced Dr. Thiel as party leader from August 20 to September 14.

Excellent operational and logistic support was provided from the Arctic Research Laboratory at Point Barrow, Alaska by director Max Brewer and his staff. The U.S.S. Staten Island provided exceptionally good support for the seismic shots at sea.

Thirty shots were successfully recorded on a seismograph located at Point Barrow. Sixteen of these shots were fired in the Chukchi Sea and 14 on land. Eleven shots were fired from the U.S.S. Staten Island for a reversed profile extending 320 Km. northwest of Point Barrow. Using a weasel or small motor boat for transportation,

14 shots for two reversed profiles were set off within 30 Km. at the recording seismograph. One shot was fired from the U.S.S. Burton Island 16 Km. to the north.

The offshore end of the long refraction profile at sea was recorded on ice island Arlis II by personnel from the Lamont Geological Observatory. Their data is not covered in this report but will be integrated into the final report.

A series of shots were attempted along a line between Point Barrow and Umiat, 250 Km. to the southwest using pontoon equipped Cessna 180 aircraft. These shots were not successfully recorded because of the difficulty in burying shots deep enough in the tundra or shallow lakes to provide sufficient energy coupling from the explosives into the earth.

RECORDING EQUIPMENT

The shots were recorded on a SIE VLF seismograph permanently located on land about 2 Km. southeast of the Arctic Research Laboratory. A spread of eight Hall-Sears 2-cycle seismometers were used. Low frequency arrivals from a distance of 320 Km. were successfully recorded with this equipment. For local shots the geophones were spaced about 100 meters apart along a line bearing S. 43 E. The geophones on the ends of the spread were extended an additional 800 meters to record shots at sea. All geophones were buried about 1 foot in the permanently frozen earth.

LOCAL SHOTS

A series of shots were fired within 30 Km. of the receiving site. A weasel or small boat was used for transportation to the shot point. Military U.D.T. C-3 explosives were used. The charges were placed in 3 to 10 feet of water and detonated with electric caps. Communication between the shot point and receiving site was maintained by marine radio using frequencies of 4637.5 or 1652 kc. Time control was provided by a radio at the shot point which transmitted a constant frequency signal that was cut off at the instant of detonation. This signal was recorded on one trace of the seismogram at the receiving site. This system provided accurate time control for shots within 10 km. of the receiving site but was not reliable for greater ranges during periods when radio reception was poor. Positions and distances of land shots were plotted on a map of the area, off-shore shot positions were determined by triangulation.

SHOTS AT SEA

Shooting at sea was done from an icebreaker using 50-pound blocks of cast TNT. Each charge was packaged on the deck of the icebreaker, lowered overboard with a crane, and suspended from oil drums. The suspended charge was towed away from the icebreaker by a landing craft. An electric blasting cap was then attached to the 300 to 500 foot length of primacord extending from the charge.

The shipboard fathometer was used to determine the depth of water at the shot point. Charges were suspended at a depth that would provide

maximum transfer of energy into the surrounding media and eliminate production of multiple source effects by an expanding and collapsing bubble pulse. This was done by placing the charges at depths where the expanding gas bubble would just break the surface according to the empirical formula: charge depth (ft.) = $\frac{1}{2}(\text{charge size (lbs.)})^{1/3}$.

Radio fixes were used to determine the shot location in most cases. Solar fixes were used when radio reception was poor. A check on four shot distances was provided by Henry Kutschale of the Lamont Geological Observatory who recorded water wave arrivals at ice island Arlis II. Distances agreed to within less than 3 Km. for shots 26, 27, 28, and 35. A distance error of 3 Km. was assumed for all shots.

A five minute countdown was transmitted from the icebreaker before each shot. At the receiving site a manually activated circuit produced a time mark on the seismogram at zero shot time. Aboard ship the Greenwich Civil Time of the shot was noted within one-half second and at the receiving site a WWV signal was recorded on one trace of the seismogram. The manually produced time mark agreed with the G.C.T. of detonation to within one-half second for all shots recorded when WWV reception was good. Arrival times were determined from the zero time mark including an assumed error of one-fourth second.

OBSERVATIONS IN THE POINT BARROW AREA

Nineteen shots were recorded from distances within 30 Km. of the seismograph at Point Barrow. The pertinent information for

these shots is given in Table 1 and the location of most of them is shown in Figure 1. A reversed profile bearing S. 43 E. was completed and a reversed profile normal to this bearing was partially completed.

Standard refraction formulas for dipping layers were used to interpret the data. The data are shown in Figure 2. There is a thin layer of permanently frozen earth at the surface which has a velocity of 3.40 Km./sec. Direct arrivals through this layer were obtained only with the two nearest shots. The material below the permafrost has a velocity of 2.50 Km./sec. and extends to a depth of 0.35 Km. beneath the center of the geophone line. The next layer is 0.72 Km. thick, dips 1°50' to the northwest, and has a velocity of 3.11 km./sec. At a depth of 1.07 Km. is a 4.82 km./sec. velocity layer dipping 2°40' to the northwest.

Good velocity control to a depth of 1 Km. below the Point Barrow area was obtained in the direction of the refraction profile at sea and the results agree well with those obtained by reflection shooting in this area in connection with exploration of the 4th Naval Petroleum Reserve.

THE LONG REFRACTION PROFILE

Eleven shots were fired from the U.S.S. Staten Island for a 320 Km. profile in the Chukchi Sea. The profile is on the continental shelf, parallel and very near the edge of the Arctic Ocean basin. The shot locations are shown in Figure 3, shot information is listed in Table 2, and the travel time plot is shown in Figure 4.

In this preliminary interpretation of the long refraction profile, horizontal layering was assumed and cross-over distances were used to

TABLE 1. - Shot information, Point Barrow area

Shot	Distance, km. ^{1/}	Date 1961	Charge size, lbs.	Shot vehicle	First arrival, sec.	Comments
1	.76	July 10	10	Weasel	.302	
2	4.21	10	15	do.	1.425	
3	.10	11	2.5	do.	.030	
4	1.62	11	10	do.	.672	
5	.10	11	2.5	do.	.028	
6	.84	11	5	do.	.331	
7	1.45	11	10	do.	.555	
8	9.40	12	30	do.		No time control
9	16.60	12	120	do.		First arrival not clear
10	10.20	14	40	do.		No time control
11	10.20	14	40	do.		Do.
12	10.64	17	40	do.		Do.
13	22.8	17	80	do.		Do.
14	4.06	18	20	Small boat	1.485	
15	1.82	18	20	do.	.732	
17	6.2	Aug. 5	20	Weasel	1.907	
18	7.15	5	20	do.	1.912	
31	7.4	26	1500	Small boat	2.52	Water depth 21 ft.
37	6.04	Sept. 11	20	do.	2.54	Water depth 35 ft.

^{1/} Distance from shot point to nearest geophone.

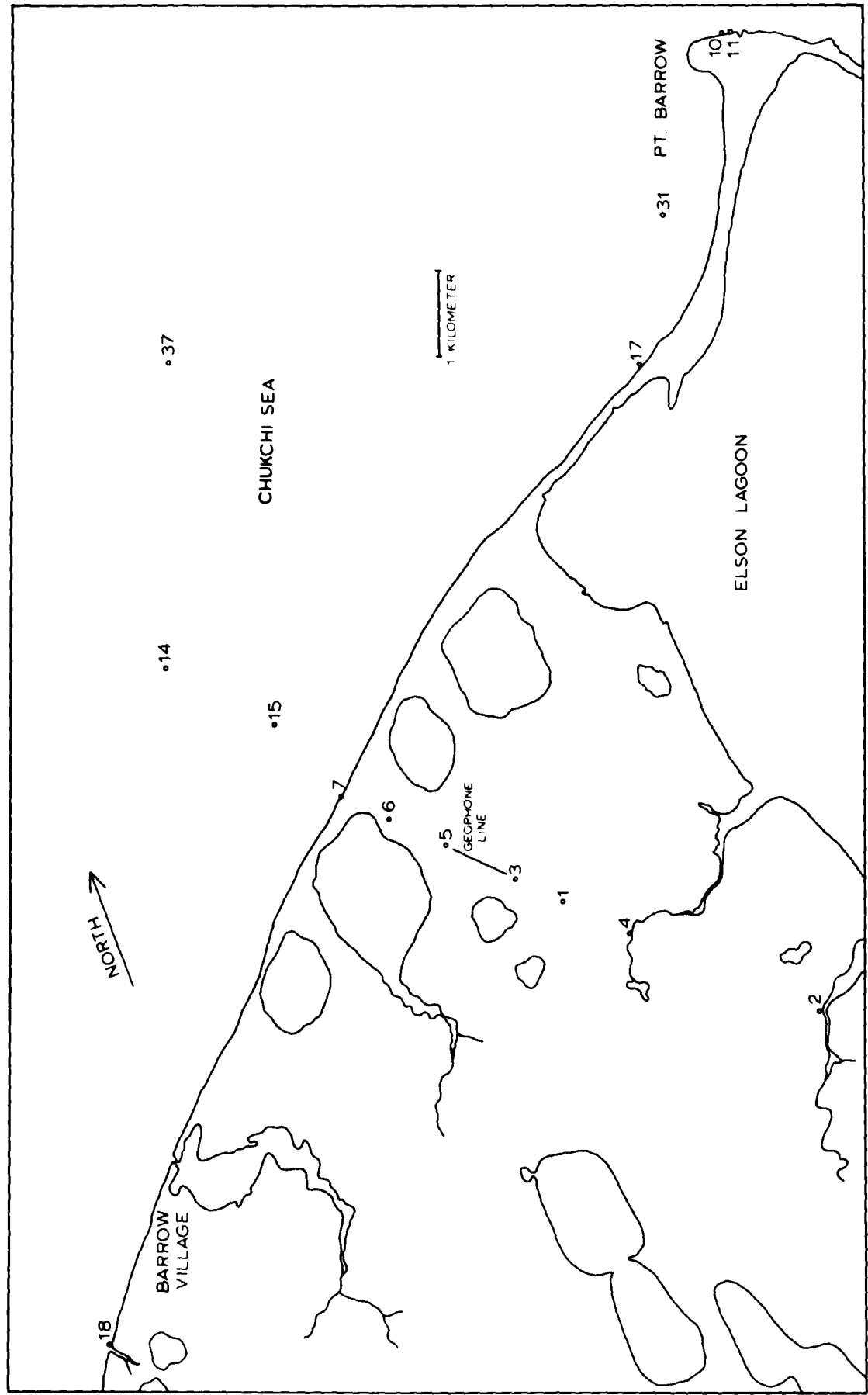


FIGURE 1

REVERSED SHORT REFRACTION PROFILE - BARROW, ALASKA

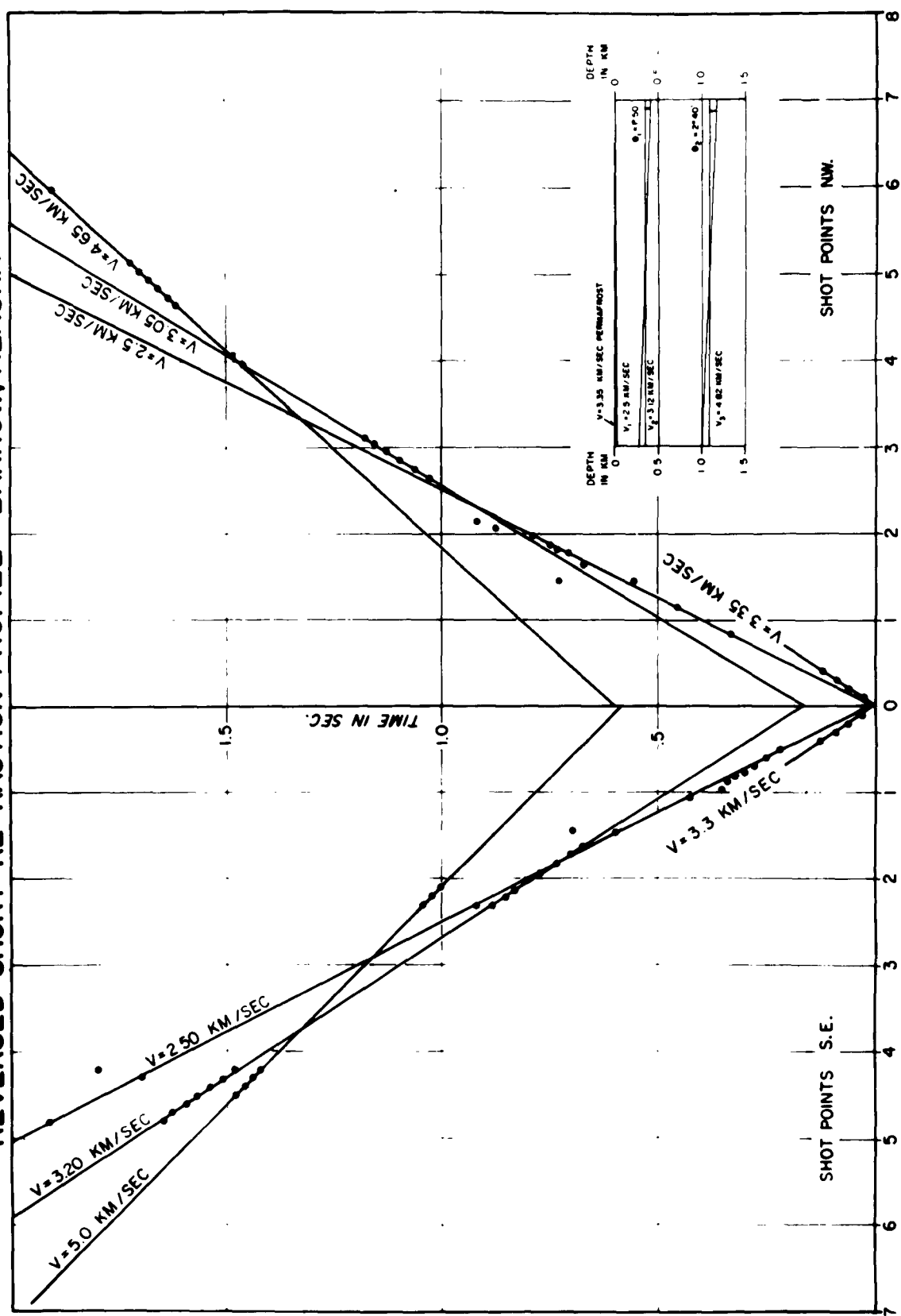


FIGURE 2

TABLE 2. - Shot information, shots at sea

Shot	Distance, km.	Date 1961	Charge size, lbs.	Charge depth, ft.	Water depth, fathoms	Latitude North		Longitude West		1st Arrival, sec.	Comments
						Deg.	Min.	Deg.	Min.		
16	16.0	July 24	50	16	84	71	29	156	45		No time control
19	37.74	Aug. 22	150	26.5	40	71	35	157	21	8.20	
22	111.4	23	600	42	27.5	72	05	158	46	21.08	
23	147.6	23	700	45	25.5	72	21	159	24	26.96	
24	186.5	23	800	46	26.5	72	37	160	09	32.17	1st arrival not clear Do. Do.
25	219.4	23	900	48	27.5	72	48	160	56	36.70	
26	256.1	24	1100	50	148.5	73	06	161	30		
27	292.6	24	1200	53	75	73	21	162	14		
28	320.7	24	1300	54	99.5	73	31	162	54		15.54 44.47 25.80
34	73.2	Sept. 4	350	35	35	71	54	157	47		
35	277.2	4	1500	57	159.5	73	26.7	161	06		
36	126.0	11	800	46	19	71	15	160	00		

Recording seismograph at 71° 23.4' N., 156° 28.6' W.

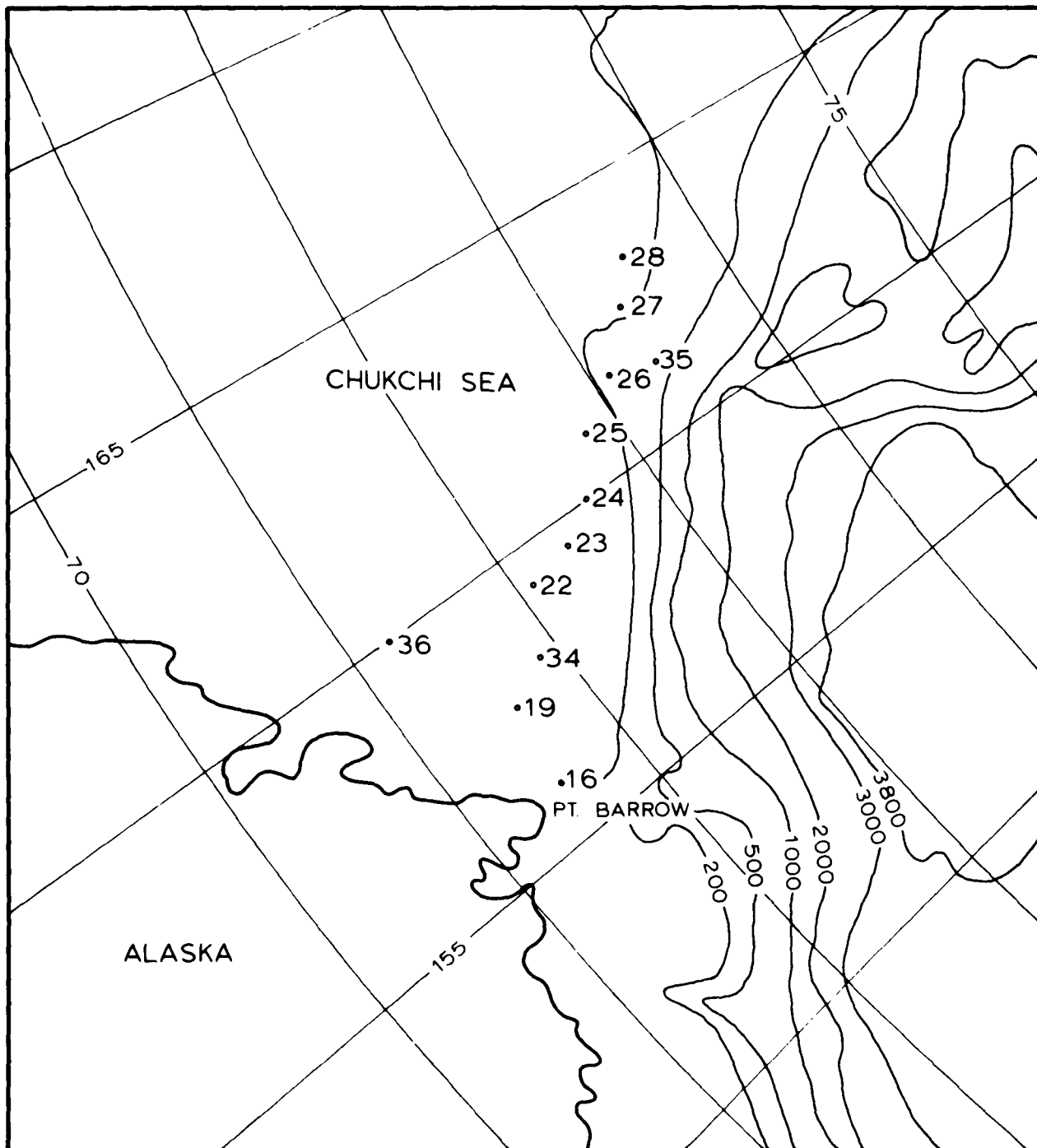


FIGURE 3

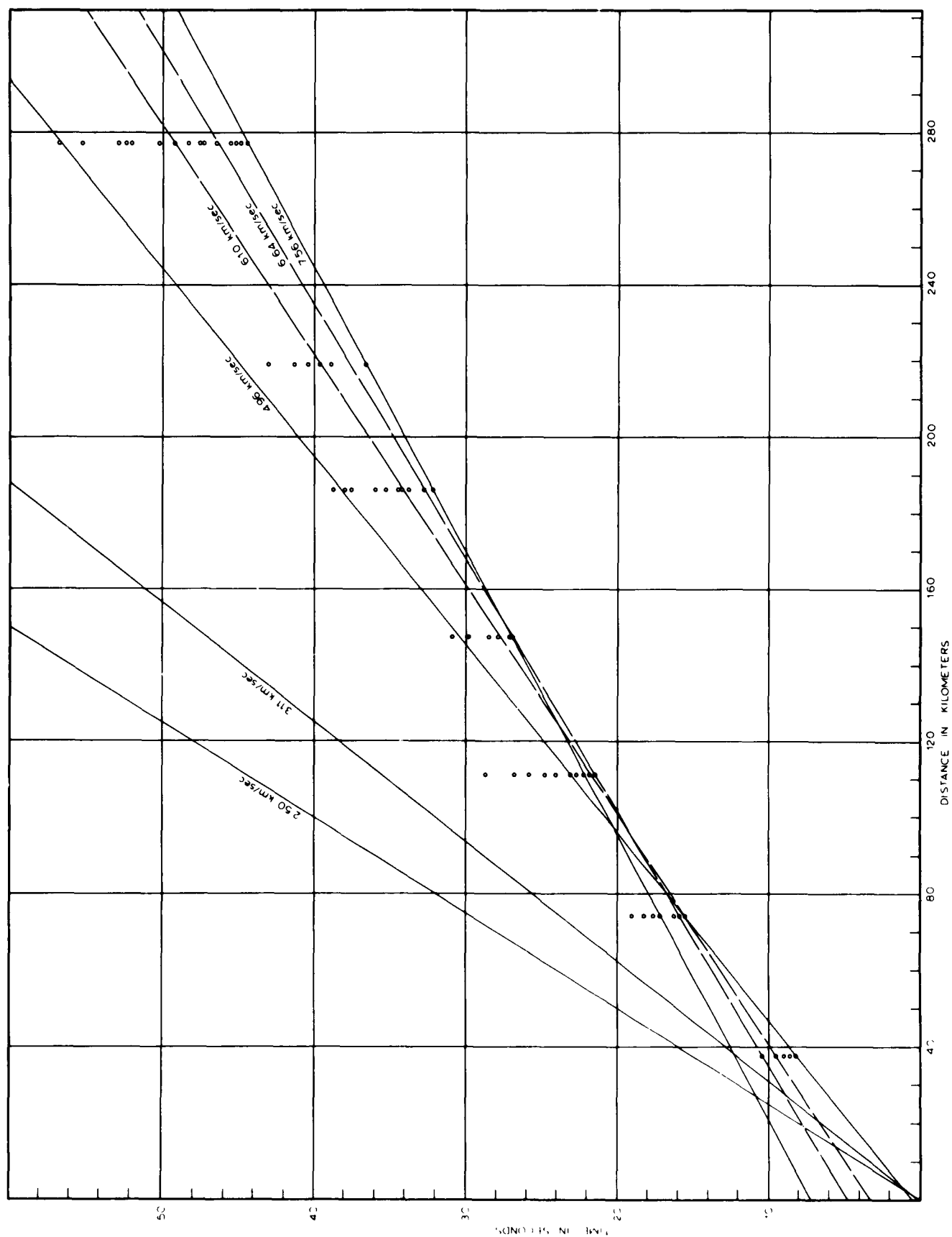


FIGURE 4

establish the depth to the layers. The horizontal layering assumption is not unrealistic since the profile parallels the continental margin.

The velocity between the 4.96 and 7.56 km./sec. layers is not clear on the travel time plot. The following three interpretations suggested by later phases and satisfying first arrival conditions were considered.

The first interpretation produces a model with velocity layers of 2.50, 3.11, 4.96, 6.10 and 7.56 km./sec. Cross-over distances are 2.1, 4.4, 75.6, and 122.5 km. The thickness of these layers is 0.36, 0.89, 11.9 and 15.3 km. This model results in a depth of 28.5 km. to the 7.56 km./sec. layer. It was assumed here that the 2.50 and 3.11 km./sec. layers extend the entire length of the profile. This is not the case but the error produced by this assumption for 1 km. of material is small compared with the depth of interest. A dubious first arrival from shot 22 was neglected in this interpretation but was considered for models two and three.

The second interpretation would produce a model with velocity layers of 2.50, 3.11, 4.96, 6.64, and 7.56 km./sec. with cross-over distances of 2.11, 4.4, 81.4 and 148.1 km. Thicknesses would be 0.36, 0.89, 15.2, and 14.5 km. for a total of 31.0 km. to the basement layer.

The third interpretation includes the possibility of 6.10 and 6.64 km./sec. layers. Velocity layers would be 2.50, 3.11, 4.96, 6.10, 6.64, and 7.56 km./sec. with cross-over distances of 2.1, 4.4, 75.6, 93.0, and 148.1 km. for thicknesses of 0.36, 0.89, 11.9, 6.4 and 12.5 km. For this interpretation the depth of the 7.56 km./sec.

layer would be 32 Km.

The three models are compared in Figure 5. They all predict a depth of about 30 Km. to the 7.56 Km./sec. layer.

SUMMARY

The shallow structure underlying Point Barrow, Alaska, was determined by seismic refraction methods. Data for a 320 Km. reversed refraction profile in the Chukchi Sea northwest of Point Barrow was obtained. A preliminary interpretation was made using the data from one end of the profile. This interpretation results in a depth of about 30 Km. to a 7.56 Km./sec. basement layer.

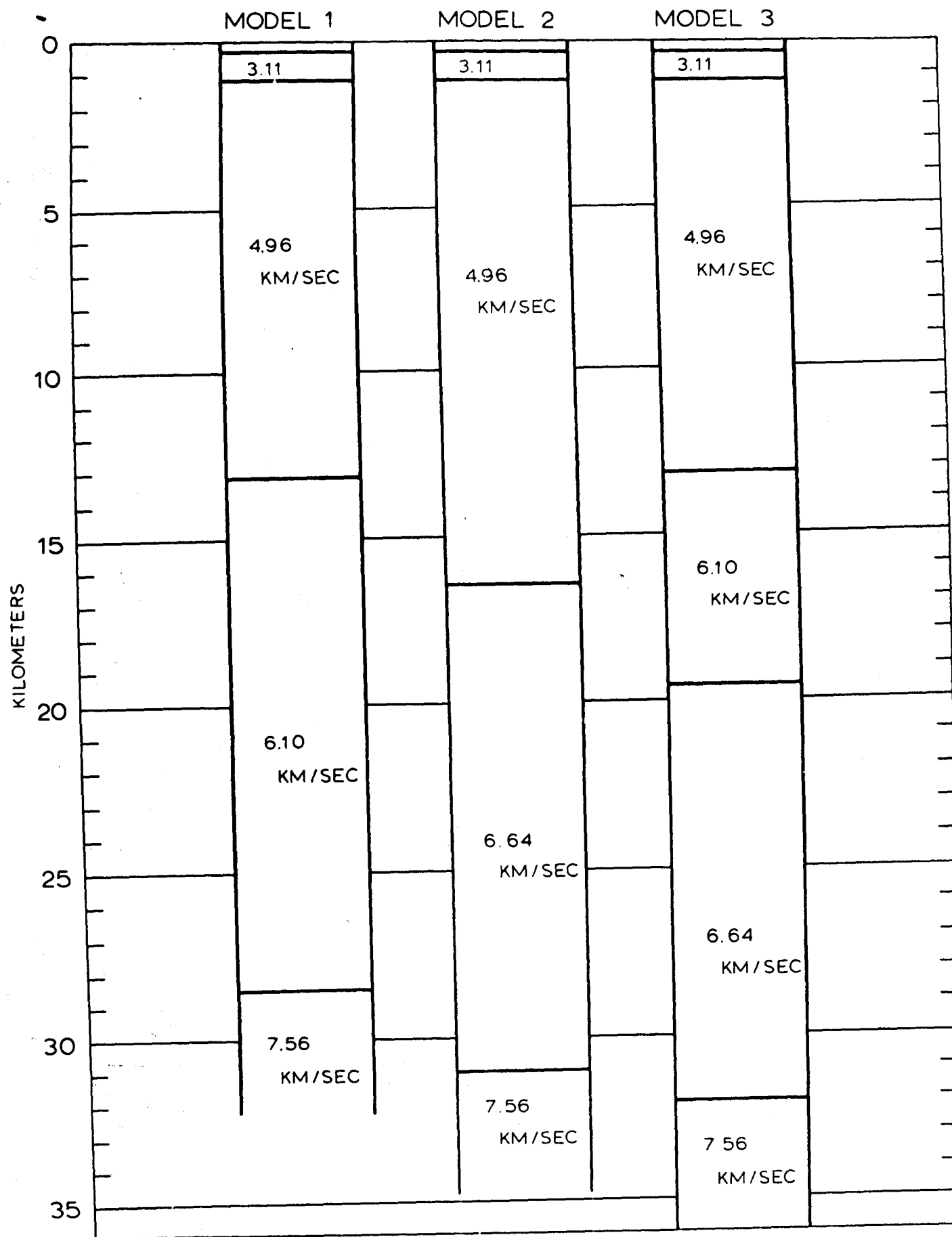


FIGURE 5